

NASA Nuclear Flight Safety – New Protocols for Safety and Mission Assurance

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Over the past 4 years, the United States (U.S.) Government has issued several new National policies that fundamentally change the approach to nuclear flight safety for aerospace applications, including the complete revision of the Federal policy for handling launch of spacecraft containing space nuclear systems. In response, the National Aeronautics and Space Administration (NASA) is updating its nuclear flight safety program while still maintaining consistency with other Federal policies, international conventions, and NASA's own policies. The recently-completed revision of the NASA Procedural Requirements (NPR) document for nuclear flight safety is a key step in the evolution of NASA policy and practice in this area. This paper will briefly describe the more significant changes in the new NASA NPR.

I. BRIEF OVERVIEW OF NATIONAL POLICY CHANGES

In December 2017, the President of the United States (the President) issued “Presidential Memorandum on Reinvigorating America’s Human Space Exploration Program,” referred to as Space Policy Directive-1 (SPD-1)¹. SPD-1 charges NASA to lead “an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities,” as re-emphasized by the 2020 National Space Policy.² New direction specific to space nuclear power and propulsion (SNPP) was also promulgated in the same timeframe in the form of 2019’s National Security Presidential Memorandum (NSPM) 20, “Presidential Memorandum on Launch of Spacecraft Containing Space Nuclear Systems,” which establishes an updated and risk-informed process for launching space nuclear systems³, and 2020’s Space Policy Directive 6, “Memorandum on the National Strategy for Space Nuclear Power and Propulsion,” which “establishes a national strategy to ensure the development and use of SNPP systems when appropriate to enable and achieve the scientific, exploration, national security, and commercial objectives of the United States.”⁴

This series of National policy directives enables NASA to evolve its nuclear flight safety program while still maintaining consistency with other Federal policies, international conventions, international guidance (including the Safety Framework for Nuclear Power Source Applications in Outer Space)⁵ and NASA’s own policies, as well as leveraging decades of experience in the area of nuclear flight safety. This paper will briefly describe the recently-issued NASA NPR document for nuclear flight safety, focusing on the changes prompted by the recent Federal policy changes and other influences. This new document, issued in February 2022, is NPR 8715.26, “Nuclear Flight Safety.”⁶ It is publicly available and is the first complete re-write of NASA nuclear flight safety policy in over 20 years.

II. ROLES AND RESPONSIBILITIES

Many roles and responsibilities are natural extensions of long-held NASA policies and practices, including the delineations between programmatic, institutional, and technical authorities, as defined in NASA Policy Directive (NPD) 1000.0 (Ref. 7). However, some changes stem from other considerations, and these are described below.

First, and importantly, the NASA Administrator has the responsibility of providing nuclear launch authorization for NASA-sponsored missions that fall within Tier I or Tier II, as those terms are defined in NSPM-20. The previous Federal policy required Presidential authorization in these situations (though it used different terminology in distinguishing between categories). Presidential authorization is still required for NASA-sponsored missions that fall within Tier III. The NASA Administrator is also responsible for ensuring that NASA fulfills its responsibilities related to the standing Interagency Nuclear Safety Review Board (INSRB), a responsibility that also flows directly from NSPM-20.

Another key change in roles and responsibilities relates to the NASA Mission Directorate Associate Administrator, who designates an individual for coordinating with other entities that may be contributing a space nuclear system or other radioactive material to a given flight and ensuring that nuclear flight safety requirements are being addressed in a manner that

considers the entire manifest. This responsibility was re-cast in the NPR in acknowledgement of the greater degree of cooperation and collaboration between NASA programs and projects when it comes to ride shares, so as to ensure that a holistic assessment is being performed for any particular flight.

For the NASA Chief of Safety and Mission Assurance, the responsibility of appointing a nuclear flight safety lead and an interagency review representative has also been re-cast. First, some straight-forward changes were made that re-titled these positions, consistent with NSPM-20 and more recent personnel naming conventions. Importantly, the new NPR now includes language to encourage that these two roles be filled by different personnel. In the past, a single individual has sometimes filled both roles, and this has the potential to erode the independence between the internally-oriented nuclear flight safety technical authority role and the externally-oriented interagency review role. While the two positions are complimentary, a sufficient degree of independence minimizes concerns about internal versus external information sharing and allows NASA safety and mission assurance personnel to be very clear when they are representing a NASA dissent versus an interagency concern.

III. MISSION CATEGORIZATION

Prior to 2019's Federal policy change, all radioactive material was categorized solely based on its A2 mission multiple, except for reactors which automatically required the full Federal process. A2 is a concept developed by the International Atomic Energy Agency for use in land, sea, and air radioactive material transport to normalize the relative hazard of different radioisotopes based on the exposure that would occur under specified accident assumptions. Though these accident assumptions do not directly consider space launch or return mishap conditions, A2 has long been used in nuclear launch authorization policy as a convenient means of fulfilling the same basic function.

NSPM-20 took the previous "one size fits all" approach to the launch of space nuclear systems and created three tiers that consider the fuel (for reactors), the A2 mission multiple, and the as-analyzed probability of exceeding specified dose limits for a maximally-exposed individual. NPR 8715.26 directly utilizes these tier criteria for categorizing space nuclear systems. It also creates the basic infrastructure within NASA's context for assessing the appropriate tier at three stages during mission formulation and implementation. The interplay between the relevant Federal requirements, the assessed tiers, and the as-analyzed exposure exceedance probabilities necessitates a staged approach to tier determination.

For all other radioactive material (i.e., not space nuclear systems), NPR 8715.26 retains the sole use of the A2 mission multiple for risk-informing the nuclear flight safety process. Some modest changes are made to the delineation points between different categories, and the associated launch or return authorizing official, but in general the new NPR tracks with past practices in this area.

IV. NUCLEAR FLIGHT SAFETY REQUIREMENTS

For the purpose of describing what has or has not changed, the requirements within NPR 8715.26 are grouped into nuclear safety analysis and review, launch authorization, radiological contingency planning, and other requirements. Each is discussed in the following sub-sections.

IV.A NUCLEAR SAFETY ANALYSIS AND REVIEW

NSPM-20 carried forward the requirement that a nuclear safety analysis report (SAR) will be performed for flight of all space nuclear systems. NPR 8715.26 encodes this requirement and also carries forward the traditional approach to preparation of a safety analysis summary (a less detailed analysis relative to a SAR) for launch of elevated quantities of radioactive material that are not space nuclear systems. These nuclear safety analyses require significant expertise and coordination, and NPR 8715.26 focuses on ensuring that this coordination is well-managed and timely.

Unlike its predecessor, NSPM-20 does not require an interagency nuclear safety review for all space nuclear system launches. Federal Government launches that fall into Tier I do not require such reviews. For commercial launches, such reviews only occur at the request of the Secretary of Transportation. NPR 8715.26 encodes these tenets, operationalizes related aspects described in NSPM-20 (such as the identification and communication of gaps or omissions in the nuclear safety analysis), and creates an analogous internal-to-NASA review for NASA missions that fall in to Tier I or otherwise involve quantities of radioactive material defined to warrant such a review. In the case of INSRB-reviewed missions, an INSRB safety evaluation report (SER) is generated. For internally-reviewed missions, a radiological safety review (RSR) is generated.

IV.B LAUNCH AND REENTRY AUTHORIZATION

In moving from the nuclear safety analysis and review process to the launch authorization process, NPR 8715.26 carries forward a concept previously used, that of soliciting "Agency Views." As defined in the NPR, this term refers to "a formal process of transmitting the mission SAR and SER to the Head of an INSRB-participating organization and requesting any feedback that the Agency Head wishes to be integrated into the

launch authorization decision.” However, unlike past practice, NPR 8715.26 narrows down the instances when the “Agency Views” process would be used to those in which: (i) the SER concludes that the nuclear safety analysis is of insufficient quality to support decision making, (ii) the INSRB has been unable to reach unanimity on the SER contents and a formal dissent by an INSRB member is being attached to the SER, or (iii) an agency represented on the INSRB has specifically requested the opportunity to provide an Agency View.

For requesting launch authorization or concurrence, the authority level for Tier III missions is set to the Executive Office of the President, and for Tier II and Tier I missions to the NASA Administrator, consistent with NSPM-20. For flight of “other radioactive material,” the authorizing official (either the Chief of Safety and Mission Assurance or the nuclear flight safety officer) and the timeline of the authorization request (4 months prior to launch versus 3 months) are varied based on a general risk-informing of the activity.

In all cases, if the end-of-mission plan involves return of the space nuclear system or other radioactive material in a known timeframe, then return authorization is addressed as part of launch authorization. Otherwise, a separate return authorization occurs when the salient details become available. Note that deliberate reentry of a space nuclear system to Earth is not customary, and end-of-mission planning for such systems is subject to the requirements of SPD-6.

IV.C RADIOLOGICAL CONTINGENCY PLANNING

Radiological contingency planning, as an element of broader emergency management and mishap preparedness capabilities, remains an important part of the flight of a space nuclear system or other large quantity of radioactive material. Radiological contingency planning involves a significant degree of coordination planning amongst a large set of stakeholders. In NASA’s governance model, it requires integration of responsibilities between NASA programmatic authorities, NASA institutional authorities, NASA technical authorities, NASA contractors, other governmental entities, and partners.

NPR 8715.26 implements a flexible approach to planning and execution in this area to support a high degree of coordination while also encouraging a scaling of the needed capabilities for radiological contingency planning that considers the specific characteristics of a given mission. In particular, NPR 8715.26 requires the development and execution of a negotiated mission-specific plan for addressing radiological contingency that has defined content commensurate with a mission’s scope and context.

Development of the negotiated plan is led by the NASA Mission Directorate (as the lead programmatic authority) and the Center Director affiliated with the applicable range (as the lead institutional authority), in coordination with the Office of Safety and Mission Assurance. The plan is developed in cooperation with several other key NASA headquarters offices, the preparer of the nuclear safety analysis used for launch approval, relevant US government agencies, relevant local and State authorities, and any international partners.

The features of the plan include the development of a radiological contingency risk posture, consistent with the broader principle of using established risk postures to implement a “risk leadership” philosophy toward the goal of increasing decision velocity, as described in Section 3.4.1 of NPD 1000.0 (Ref. 7). The plan features also include the development, reporting, independent review, and acceptance by relevant authorities of an assurance case tailored to the defined risk posture to substantiate that sufficient radiological contingency controls and mishap preparedness capabilities exist.

IV.D OTHER REQUIREMENTS

In addition to the requirements described in the above sub-sections, there are several requirements that warrant mentioning. First, NPR 8715.26 acknowledges that nuclear safety considerations are relevant throughout the life-cycle, including during activities like launch vehicle selection, managing radiation exposure to equipment, managing access to the spacecraft and a space nuclear system, managing autonomous control of a space nuclear system (where applicable), biasing aimpoints for Earth gravity assists (where applicable), etc.

NPR 8715.26 also includes a requirement related to monitoring of the continued applicability of the nuclear safety analysis and review following launch authorization, including consideration of the NSPM-20 Safety Guidelines. Two potential approaches to this monitoring are described in an appendix to the NPR.

Regarding decommissioning and disposal, NPR 8715.26 promulgates the requirements of SPD-6, which address disposal of Earth-orbiting spacecraft carrying a space nuclear system.

Finally, as a means of balancing public transparency with protection of sensitive information, NPR 8715.26 requires that a publicly-available executive summary of the nuclear safety review be produced for NASA-sponsored missions.

V. ADDITIONAL ASPECTS

A few additional aspects of NPR 8715.26 are described in the following sub-sections.

V.A. COMMERCIAL LAUNCHES

The process for launching space nuclear systems on commercial launches is still evolving. As stated in NSPM-20, the “Secretary of Transportation, or the Secretary’s designee, is the licensing authority for commercial launches of spacecraft containing space nuclear systems.” Meanwhile, the Nuclear Regulatory Commission and the Department of Energy retain their traditional roles as terrestrial nuclear authorities. NASA continues to work with these other government agencies through bilateral and multilateral forums, toward clarifying roles, responsibilities, and processes for NASA activities that involve space nuclear systems or other radioactive material on commercial launches. For now, NPR 8715.26 continues to levy nuclear flight safety requirements on NASA personnel as appropriate, acknowledges the role that interagency equivalences are expected to play in addressing “whole-of-government” situations, and directs NASA personnel to consult the Office of General Counsel and the Office of Safety and Mission Assurance anytime that NPR applicability is not clear.

V.B. TAILORING

NPD 1000.0 establishes, at the highest level, NASA’s perspective on tailoring of requirements. It states, “Tailoring is the process used to adjust or seek relief from a prescribed requirement to meet the needs of a specific program, project, or activity. Among other things, it enables agility without sacrificing necessary rigor in development and testing. Tailoring is both an expected and accepted part of establishing proper requirements, as it is recognized that each program, project, or activity has unique aspects that may warrant a modification from the nominal process without sacrificing the likelihood of achieving success in a safe, efficient, and economical manner.”

Consistent with the above, NPR 8715.26 (like all safety and mission assurance directives) contains language that addresses requests for relief from the requirements in the directive. The Chief of Safety and Mission Assurance is the approving authority for requests for relief from NASA nuclear flight safety requirements. The NPR goes on to state that, non-conformances with Federal nuclear launch authorization direction in NSPM-20 or other applicable regulatory-agency requirements will be elevated to the Administrator, and that any non-conformances will be formally communicated to the Director of the Office of Science and Technology Policy.

V.C CATEGORICAL RELIEF

Historically, NASA has required that Headquarters formally concur on every flight of radioactive material, regardless of circumstance. This posture leads to

Headquarters reviews even in cases where no value can be added by the review, though awareness of the forthcoming flight of the radioactive material does provide value (both in terms of promoting tracking relative to terrestrial licenses and in terms of giving informed advice in the case of a mishap). To address this situation, NPR 8715.26 introduces the concept of a “categorical relief.”

In cases where the Office of Safety and Mission Assurance, in partnership with the Office of the Chief Health and Medical Officer, have determined a priori that a specified amount of radioactivity is adequately managed by routine payload safety, ground safety, and crew safety policies and practices, without additional assessment by the nuclear flight safety program, a notification-only posture is adopted. In other words, when the prescribed conditions are met, a NASA program or project can follow the steps of notifying NASA headquarters of the forthcoming flight but need not wait for a concurrence letter before proceeding. The limits for the categorical relief concept are set on a mission-agnostic basis to offer a stable and reliable means of appropriately risk-informing review for these situations. In addition to receiving and reviewing the notifications, the Office of Safety and Mission Assurance conducts an annual review of all invocations of the categorical relief process, and any adverse trends or discrepancies are reported to the relevant personnel.

V.D ADDITIONAL AIDS

Though not re-produced here, NPR 8715.26 provides several aids that may be of interest to those working in the area of nuclear flight safety. Among these are (i) explanatory information about the use of NSPM-20 and a figure and table illustrating the tiering criteria therein, (ii) a table providing general activities that occur, by life-cycle phase, and (iii) sample timelines for activities for a Tier II and Tier III NASA mission.

VI. FUTURE PLANS

Issuance of NPR 8715.26 is a major milestone in implementing NSPM-20 at an operational level. As previously mentioned, NASA will continue to work with interagency partners to improve how NASA activities integrate with the activities and governing processes of those other agencies. NASA will also continue to work within established working groups for range safety and for nuclear safety toward this same end. For example, NASA administers the INSRB created by NSPM-20, and that entity has recently issued a Trial Use guidance document to better describe how it envisions conducting its reviews. Publicly available NASA nuclear flight safety and INSRB documents can be obtained from the following website: <https://sma.nasa.gov/sma-disciplines/nuclear-flight-safety>.

NASA staff are also working on a NASA Nuclear Flight Safety Handbook to provide further detail about how NASA may approach nuclear flight safety activities for future missions using space nuclear systems. This Handbook utilizes a cross-agency development team and inherits some specific forward work from the discussions surrounding the development of NPR 8715.26.

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